SYNTHESIS STRUCTURAL AND MAGNETIC PROPERTIES OF TITANIUM DOPED MAGNESIUM ZINC FERRITE

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ABSTRACT

Magnetic ceramics or ferrites are very well established group of magnetic materials which exhibits ferrimagnetism. It possess high electrical resistivity, low eddy current and dielectric loss which makes it superior than the other ordinary magnetic oxides that contain the ferric oxide (Fe_2O_3) as their basic magnetic compounds. The ceramic magnets are widely used in high frequency transformer application. [(Mg, Mn, $F_{12}o_4$)] spinels are used in square-loop application. Ceramic materials found application in nuclear physics. In nuclear reactors ceramics are used as core components. The studies include the preparation and analysis of *Titanium doped Magnesium zinc ferrite.* Here, *Titanium doped magnesium zinc ferrite nanoparticles* (NPS) were synthesized using solid state reaction method. Titanium doping can enhance the magnetic properties of magnesium zinc ferrite in several ways these can contribute to improved magnetic properties , such as increased magnetic moment, saturation magnetization, and magnetic ordering , making titanium – doped magnesium zinc ferrite a promising material for various applications including magnetic storage, sensors, and spintronics. According to the stoichiometric equation [Mg0.9Zn 0.1TixFe2-xO4] at different values of x, (x=0.1, 0.3) are synthesised. Calcination and sintering of the samples is made by high temperature PID controlled muffle furnace which can go up to 1000°C. The structural and magnetic properties are examined using *XRD, FTIR* and *Curie temperature* analysis. From the XRD analysis it revels the phase structure and lattice parameters of the samples. XRD analysis gives maximum intensity of (h k l) values as (3 1 1) in both cases. It also reveals that no secondary phases are produced during growth. That means the specimens FCC stacking. FTIR analysis of the samples done using Fourier transformer infrared spectroscopy. From this analysis it revels the detailed atomic structure and bonding of the samples. The bands obtained reveal spinal ferrite structure. Curie temperature of the specimens is determined by *Curie temperature* apparatus for the study of magnetic properties of the specimens.

KEYWORDS: Titanium Doped Magnesium Zinc Ferrite, X-Ray Diffraction(XRD), Fourier Transformer Infrared Spectroscopy (FTIR), Nano Particles(NPS), Curie Temperature

INTRODUCTION

Magnetic ceramics or ferrites are very well established group of magnetic materials which exhibits ferrimagnetism. It possess high electrical resistivity, low eddy current and dielectric loss which makes it superior than the other ordinary magnetic oxides that contain the ferric oxide (Fe_2O_3) as their basic magnetic compounds. Ferrites are electrically nonconductive ferrimagnetic ceramics. They are usually mixtures of iron oxides such as hematite (Fe_2O_3) or magnetite ceramics, they are hard and brittle. Ceramatics are used in world widly in automobile areas, all catalytic converters in modern automobiles have ceramic honeycomb supports for the catalyst, which has been instrumental in reducing automobile exhaust emissions etc.Spinal ferrites are magnetic material having interesting properties such as low melting point, saturation magnetization and coercivety. Ferrites with these properties beneficiary in many applications such as transformer cores, ferro-fluids and gas sensors.Titanium doping can enhance the magnetic properties of magnesium zinc ferrite this making titanium- doped magnesium zinc ferrite a promising material for various applications including magnetic storage, sensors, and spintronics.

In this work, *Titanium doped Magnesium Zinc Ferrite* is synthesized by Solid – state reaction method. Structural and magnetic properties are studied by XRD, FTIR and Curie temperature analysis.

MATERIALS AND METHODS

Sample Preparation

The final electrochemical and magnetic properties of $Mg_{.9}Zn_{.1}Ti_xFe_{2-x}O_4$*(x=0.1, 0.3)* greatly depends on the processing technique. The solid state reaction is the most commonly used method for the preparation of the polycrystalline solids from the compound mixture of solid starting materials. Over normal room temperature time scales solids do not react together and it is necessary to heat them into abnormal higher temperature often to 1000 to 1500 – degree Celsius in order for the reaction to occur at an average rate. The factors on which the feasibility and rate of a solid state reaction includes reaction conditions, nature of reactants, structural properties of the reactants, surface area of the solids , reactivity and the thermodynamic free energy change associated with the reaction.

The stoichiometrically weighed raw materials are transferred to an agate mortar. It is then mixed mechanically for 21/2 hrs. The

moisture content are removed by keeping it to sunlight. It is again ground for half an hour. The contents are then transferred to a crucible.

During calcination step the solid phase reaction take place between the constituents. In this case reaction for sample can be written as

$$MgO + ZnO + Fe_2O_3 + TiO_2 \rightarrow Mg_{.9}Zn_{.1}Ti_xFe_{2-x}O_4$$

The calcination is done at 400o C for 5 hrs. The higher the calcination temperature, the higher the homogeneity and density of the final ceramic product. Pellets and toroids are made using this powder by applying pressure. The pellets are of 1.3 cm in diameter and 1 mm in thickness. Now the pellets and toroid's has to expose to sunlight before sintering.

After preheating the samples, it is mixed well and then the samples are taken in to a high controlled muffle furnace. The sample is heated up to 1000^o C.

Agate mortar with pestle

High temperature furnace

Pelletiser

pellet

Fig. 1 Synthesis of *Titanium doped Magnesium zinc ferrite*

Characterization of synthesized *Titanium doped Magnesium zinc ferrite*

Useful information about the structure of solids can be had from x ray diffraction technique using a radiation of wavelength comparable with atomic dimensions. X-ray are electromagnetic waves like ordinary light, therefore they should exhibit interference and diffraction. Bragg suggested that the diffraction pattern are produced due to the reflection of some of the incident X-ray from the various set of parallel crystal planes, called Bragg's plane, which contain a large number of atoms. Using the X-ray diffractometer, the X-ray diffraction pattern of the given sample is taken.

FTIR spectroscopy is a form of vibrational spectroscopy. Each chemical bond has a unique vibrational energy. It will be different from one compound to another depending on what other compounds bound to it. Due to this unique vibrational energy, each compound will have a unique fingerprint, or the output identifying the peak strengths at specific vibrations. This fingerprint can be used to determine compound structures, identify and characterize compounds and identify impurities.

Readings of temperature verses inductance are tabulated using Curie temperature apparatus. At Curie temperature the specimens loss their ferromagnetic property.

RESULT AND DISCUSSION

Structural Analysis

XRD analysis are carried out at ampean temperature to study the phase structure and lattice parameters. All the indexed peaks corresponds to spinal ferrite structure without any impurity phase for all compositions. The intensity of highest peak (3 1 1) shows their better crystallinity. The lattice parameter 'a'was calculated by using lattice spacing (d) and respective miller indices.

$Mg_{.9}$ $Zn_{.1}$ Ti_x Fe_{2-x} for x=0.1 and x=0.3 are synthesized by general solid state method. XRD analysis gives maximum intensity of (h k l) values as (3 1 1) in both cases. It also reveals that no secondary phases are produced during growth. That means the specimens FCC stacking.

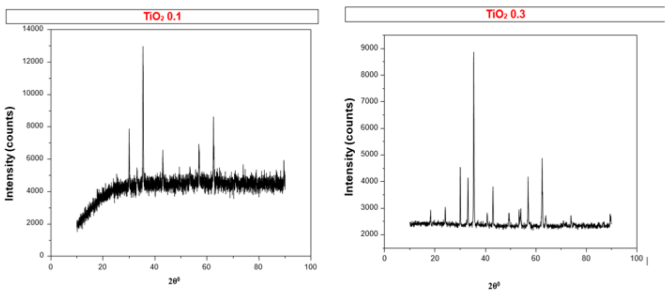

Fig. 2 *XRD* Spectra of TiO_2 (0.1) and TiO_2 (.3)

FTIR Analysis

Atomic vibrational study using *FTIR* can give the information about local chemical bonding. *FTIR* absorption spectrum was obtained between 4000 and 750 cm^{-1} spectral range at room temperature. The higher wave number band (1750-1250 cm^{-1}) and lower wave number band (1000-750 cm^{-1}) correspond to tetrahedral and octahedral lattice site ions vibration with oxygen ion respectively. These bands are characteristic bands of spinal ferrite structure. It is notice from the spectrum that the shift of the tetrahedral vibrational band towards the higher wave number ensures that the change in the cationic distribution on the lattice sites increasing Titanium concentration (for TiO_2 (0.1) = 1479.40; TiO_2 (0.3)=1525.69).

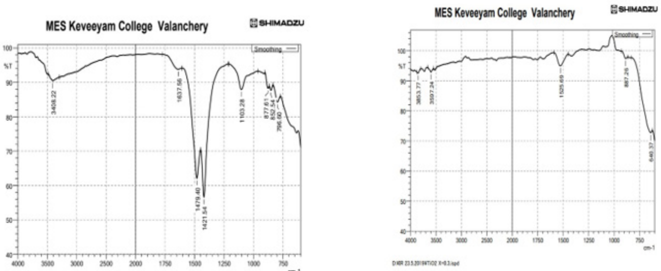

Fig.3 Percentage of Reflectance vs Wavelength of TiO2 (X=0.1) and TiO2 (X=0.3)

Measurement of Curie Temperature

The apparatus arrangement involves a strong electromagnetic bar inserted in a tabular Furnace kept vertically. The sample remains attached to the electromagnet. The temperature of the furnace slowly increased. For a certain high temperature the sample falls off indicating that it has lost its magnetism and have converted to the paramagnetic state. The temperature at which the sample falls off is the Curie temperature T_c.

Readings of temperature verses inductance are tabulated. Variations of inductance with temperature are plotted in the graph. The Curie temperature is found to be 230°C for TiO_2 (0.1), 220°C for TiO_2 (0.3).

Temperature (oC)	Inductance (mH)
34	4.3
44	4.3
54	4.3
64	4.3
74	4.3
84	4.3
94	4.3
104	4.3
114	4.3
124	4.3
134	4.3
144	4.3
154	4.3
164	4.2
174	4.1
184	4
194	3.9
204	3.9
214	3.8
224	3.8

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114	4.3
124	4.3
134	4.3
144	4.3
154	4.3
164	4.3
174	4.2
184	4.1
194	3.9
204	3.8
214	3.7
220	3.6

Table 1: Temperature and inductance of TiO2 (X=0.1) and TiO2 (X=0.3)

CONCLUSION

$Mg_{.9}$ $Zn_{.1}$ Tix Fe_{2-x} for x=0.1 and x=0.3 are synthesized by general solid state method. XRD analysis gives maximum intensity of (h k l) values as (3 1 1) in both cases. It also reveals that no secondary phases are produced during growth. That means the specimens FCC stacking.

FTIR analysis ensures about the local chemical bonding. The higher wave number band and lower wave number band correspond to tetrahedral and octahedral lattice site ions vibration with oxygen ion respectively. These bands reveal spinal ferrite structure. Shift of the tetrahedral vibrational band towards the higher wave number ensures the change in the cationic distribution on the lattice sites increasing titanium concentration.

Readings of temperature verses inductance are tabulated using Curie temperature apparatus. At Curie temperature the specimens loss their ferromagnetic property. The Curie temperature for 0.1 concentration is 230°C and for 0.3 concentration it is 220°C. As concentration of Titanium increase Curie temperature decreases.

Spinal ferrites are magnetic material having interesting properties such as low melting point, saturation magnetization and coercivity. Ferrites with these properties beneficiary in many applications such as transformer cores, ferro-fluids and gas sensors.

Zinc magnesium ferrites are useful for core material over a wide frequency range from few Hertz to several mega Hertz. So it used as core of coils in microwave frequency devices and computer memory core elements. These ferrites are used as component of electronic filter, microwave devices, magnetic switches and memory elements for computers. For memory and switching devices ferrites are used in the form of switches. In medical field ferrite are used for drug gathering and hyperthermia, separation and magnetic resonance imaging. The recent application also includes high density information storage, ferro-fluids, catalyst, sensors etc.

REFERENCES

1. G. Aruldas- Molecular structure and spectroscopy- PHI learning private limited, Delhi (2001)
2. A.C. Dunham, Christian Amtuz, Wolfgang baugmart- Process mineralogy of ceramic materials.
3. Charles kittel- Introduction to solid state physics.
4. Lines M. E. & Glass A. M.- Principals and applications of ferroelectric and related materials- Oxford university press (1997)
5. Michel.W.Barsoum- Introduction to ceramics- Institute of Physics publishing, Bristol and Philadelfia (1959)
6. J. Smith & H. P. J. Wijin- Ferrites- Physical properties of ferromagnetic oxides in relation to their technical application, Philips technical library (1959)
7. Stephan Blundell- Magnetism in condensed matter, Oxford University press, New York (2001)
8. http://www.magnetsorce.com
9. http://www.sciencedirect.com
10. http://link.springer.com
11. www.issp.ac.ru
12. http://clubtechnical.com
13. http://lambdasys.com
14. Iopscience.iop.org
15. http://mrsi.org.in
16. http://researchgate.net
17. http://www.scientific.net
18. http://www.thomasssci.com